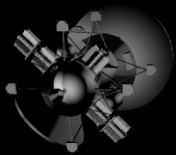
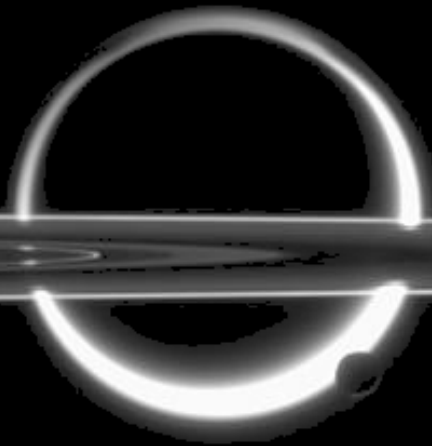


# Titan Saturn System Mission Architecture Overview

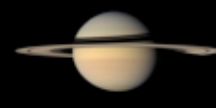
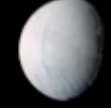
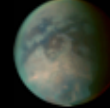
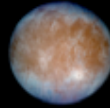


Presentation at OPFM Instrument Workshop

Presented by Kim Reh and Nathan Strange

June 3, 2008

Jet Propulsion Laboratory, California Institute of Technology Pasadena CA

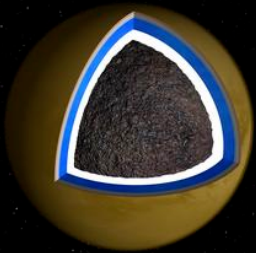


# Background

- NASA Headquarters is continuing Pre-Phase A activities in support of its selection process for the next Outer Planets Flagship Mission (OPFM), planned for November 2008
- These activities build upon results of previous Phase 1 studies: Titan Explorer (TE), Enceladus, Europa Explorer, Jupiter System Observer
- The TSSM study has been directed to respond to findings from the 2007 TE study review panels and to redesign the mission to meet new constraints specified under the revised Requirements and Ground Rules – this requires dramatic change in architecture
- Current study report is due to be complete Aug 2008 with a public release in November 2008
- Release of NASA instrument AO anticipated in early 2009



# TSSM Study Top Level Goals



- *Dedicated Titan orbiter with accommodation for ESA in situ elements*
- *Saturn System and Enceladus science*



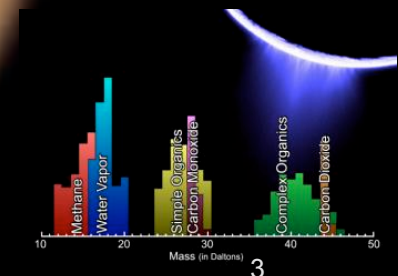
- *Scientific advancement in understanding Titan, an Earth-like system well beyond the high bar set by Cassini-Huygens*

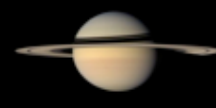
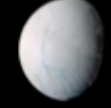
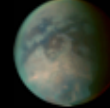
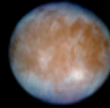


03 June  
2008

- *Total mission cost <\$2.1BFY07*

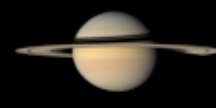
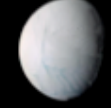
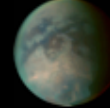
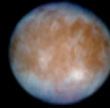
*For planning and discussion purposes only*





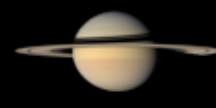
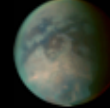
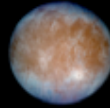
# Key Mission Drivers (for this study)

- Propulsive (Non Aerocapture)
  - Long flight times
  - Opportunity for Saturn science and Enceladus flybys
- \$2.1 Billion FY07 cost cap
  - Strong budgetary preference for Atlas class LV and single launch
- Level 1 Science: Titan, Saturn System, Enceladus
  - Titan is the primary icy moon target
- MMRTG
  - Plutonium limitations impose strict power constraints
- Option to accommodate In situ element
  - Provided by ESA
- 2016-2017 Launch years (subject to change)



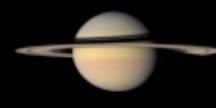
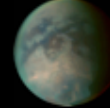
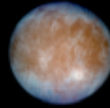
# Science Goals

- **Goal A: Explore Titan an Earth-Like System**
  - How does Titan function as a system? How are the similarities and differences with Earth, and other solar system bodies, a result of the interplay of the geology, hydrology, meteorology, and aeronomy present in the Titan system?
- **GOAL B: Examine Titan's Organic Inventory - A Path to Prebiological Molecules**
  - What is the complexity of Titan's organic chemistry in the atmosphere, within its lakes, on its surface, and in its putative subsurface water ocean and how does this inventory differ from known abiotic organic material in meteorites and therefore contribute to our understanding of the origin of life in the Solar System?
- **GOAL C: Explore Enceladus and Saturn's magnetosphere - clues to Titan's origin and evolution**
  - What is the exchange of energy and material with the Saturn magnetosphere and solar wind? What is the geysering source on Enceladus? Does complex chemistry occur in the geyser source?



# Planning Payload

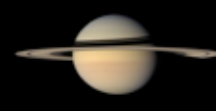
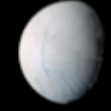
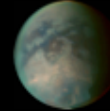
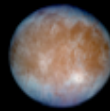
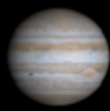
- **High Resolution Imager and Spectrometer**
  - lakes, volcanism, tectonics, surface organics, clouds and rain, atmospheric constituents
- **Mid-IR Radiometer and Spectrometer**
  - atmospheric composition, aerosols, thermal winds and surface temperatures
- **Sub-mm Sounder**
  - atmospheric composition, temperature, dynamics
- **Titan Penetrating Radar Altimeter**
  - global topography; dynamic lake topography
- **Polymer Mass Spectrometer**
  - polymers in the atmosphere; interaction of Titan's upper atmosphere with Saturn's magnetosphere; evolution of Titan's atmosphere; tholin formation
- **Magnetometer and Plasma Package**
  - Ammonia; loss rate of major gases; internal magnetic field; source of energy input to Titan's atmosphere from magnetosphere and solar wind.
- **Radio Science with Accelerometer**
  - metal core; gravity field, and its time-variation



# TSSM International Mission Concept

- **NASA Titan Orbiter**
  - Would be launched in 2016-2017
  - Radioisotope powered
  - Would reach Saturn in ten years, spend one and a half years in Saturn orbit with >4 Enceladus flybys before entering a two year Titan orbit
  - Would conduct an intensive orbital investigation of Titan and provide in situ command and data relay
- **ESA In Situ Elements** (Montgolfiere balloon, Lander)
  - Would be launched in 2016-2017 (depends on ESA launch availability)
  - Radioisotope Powered
  - Would reach Titan in ten years and spend one year at Titan in the lower atmosphere and on the surface -- potential for extended mission
  - Would conduct an intensive in situ investigation of Titan's lower atmosphere, surface and interior
- **Single Launch on Atlas V** -- Other attractive architectures assessed (e.g., Two Launch, Delta IVH, SEP) but likely exceed cost constraint



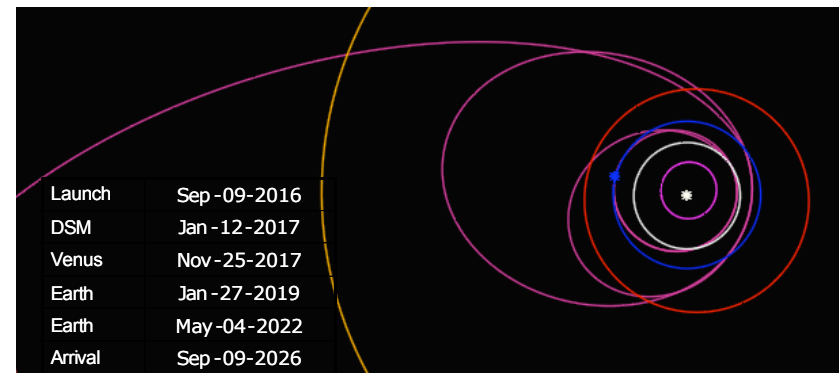
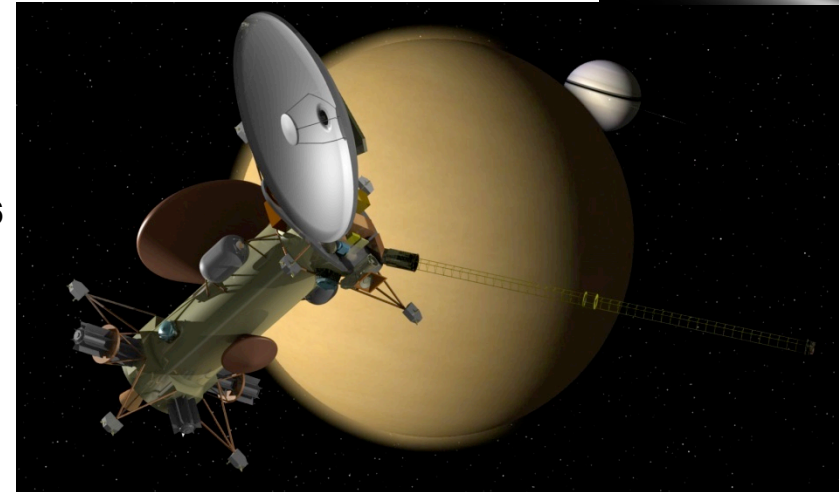


# Mission Overview

- Objective: **Titan Orbit** (primary target), **Saturn system** and **Enceladus** tour

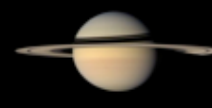
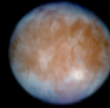
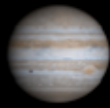
- Mission Timeline:

- Launch Atlas 551, Chemical Propulsion
  - Venus and Earth gravity assists
  - Primary Opportunity: 10 yrs to Saturn: 9/2016-9/2026
  - Backup: 9.5 yr: 9/2018-3/2028
- Saturn Arrival
  - Ring plane crossing in F-G gap, SOI at 1.3 RS
- Saturn Tour (1.8 years)
  - 6 mo. orbit after SOI to Titan with  $V_{\infty}$  of 4 km/s
  - Enceladus flybys
  - Leveraging Pump-Down to Titan  $V_{\infty}$  of 400 m/s
- Titan Orbit (2 years)
  - TOI into 950 km by 15,000 km elliptical Titan orbit
  - Aerobraking (600km), Atm. Science (750km and up)
  - ~1500 km circular, 85° polar, mapping orbit
  - 10:00 am orbit plane to 8:00 am



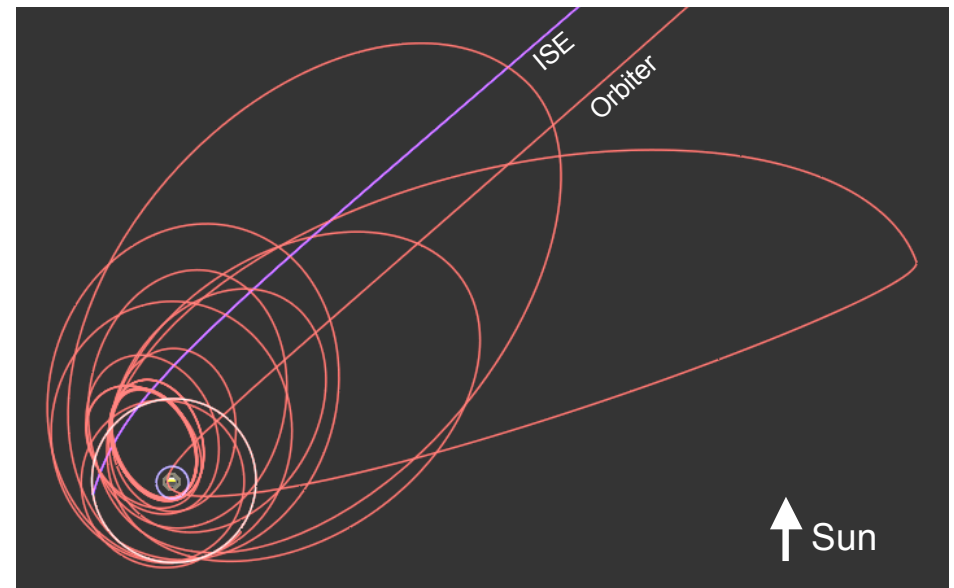
- Orbiter planning payload: 7 inst ; ~100 kg (cbe)
- Accommodates delivery of *in situ* element(s)

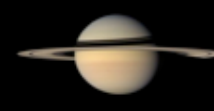
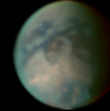
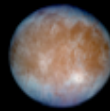
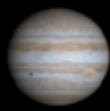




# Saturn Tour

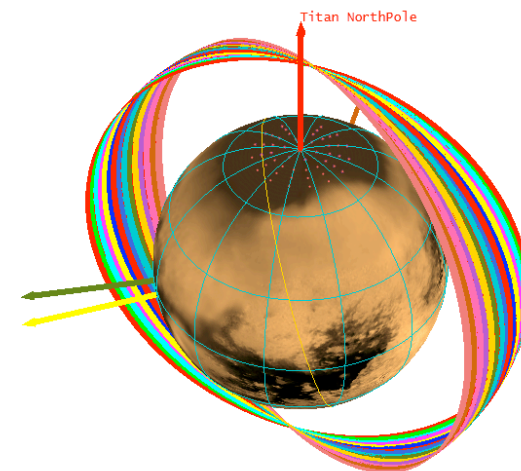
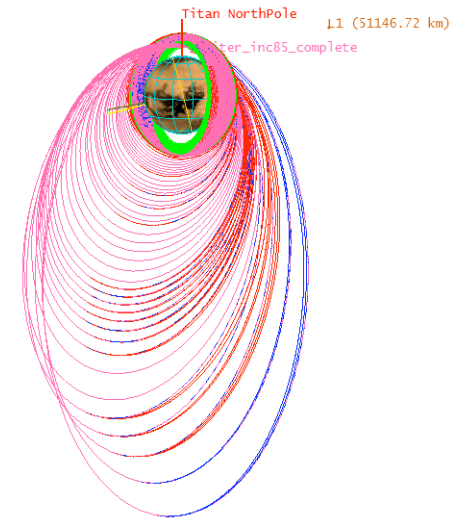
- 1.8 year Saturn gravity-assist tour from Sep 10, 2026 to July 1, 2028 with 15 Titan flybys and 4 Enceladus flybys
- Tour Consists of Three Phases:
  - Initial Slow-Down
    - 100 day transfer from SOI to first Titan flyby used to reduce energy enough to set up Enceladus flybys
  - Enceladus Flybys
    - 4 close (200-100 km) Enceladus flybys, plus additional distant flybys (10,000+ km)
  - Final Slow-Down
    - Reduces Titan  $V_{\infty}$  from 4 km/s to 0.4 km/s for efficient Titan orbit insertion.





# Titan Orbit

- Inserts into initial 950 km by 15,000 km ellipse.
- Aerobraking reduces ellipse over two months while sampling atmosphere down to 600 km.
  - ~100 passes
  - ~400 m/s delta-v savings
- Aerobraking phase is followed by a 2 year mapping phase:
  - 1500 km, circular orbit
  - Near-polar (85° inc)
  - Orbit plane varies from ~10 am to ~8 am over two year mapping period

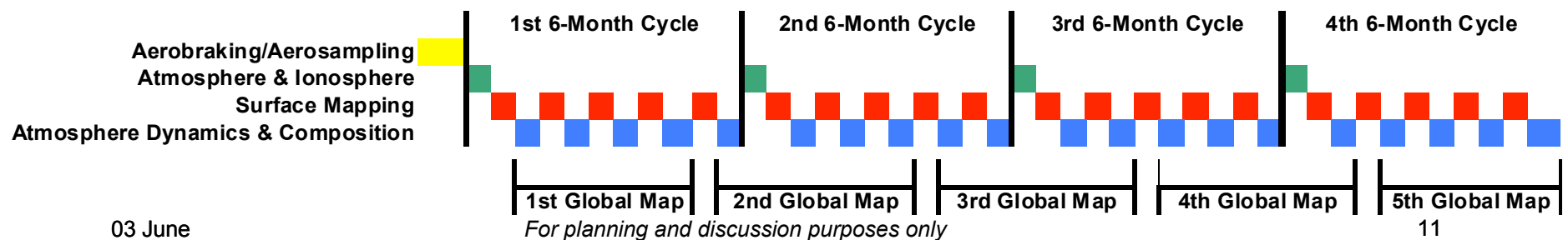
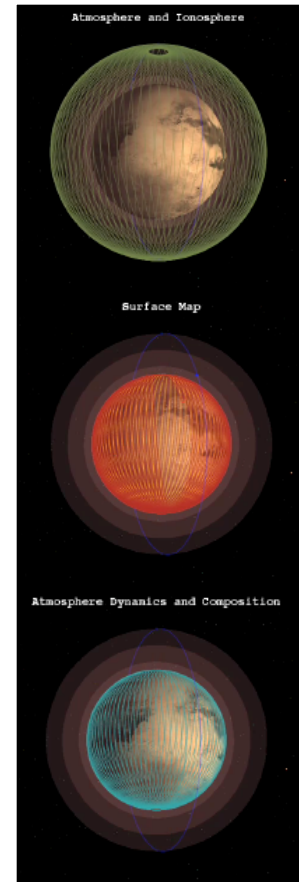


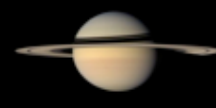
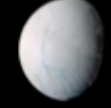
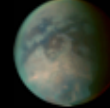
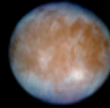
- **Three science orbit types enable global coverage**

- Atmosphere & ionosphere: identify and measure ions and neutrals globally for various Sun angles
  - Polymer Mass Spectrometer; Magnetometer and Plasma Package
- Surface map: global map in up to 4 colors; global altimetry with better than 10-m accuracy; surface spectroscopy
  - High-Resolution Imager and Spectrometer (near IR); Titan Penetrating Radar Altimeter; Magnetometer And Plasma Package
- Atmosphere dynamics and composition: measure temperatures, composition, and winds, globally
  - Mid IR Radiometer and Spectrometer; Sub-Millimeter spectral Sounder

- **Maintain each orbit type for one Titan revolution (16 days); reset at 6 month intervals**

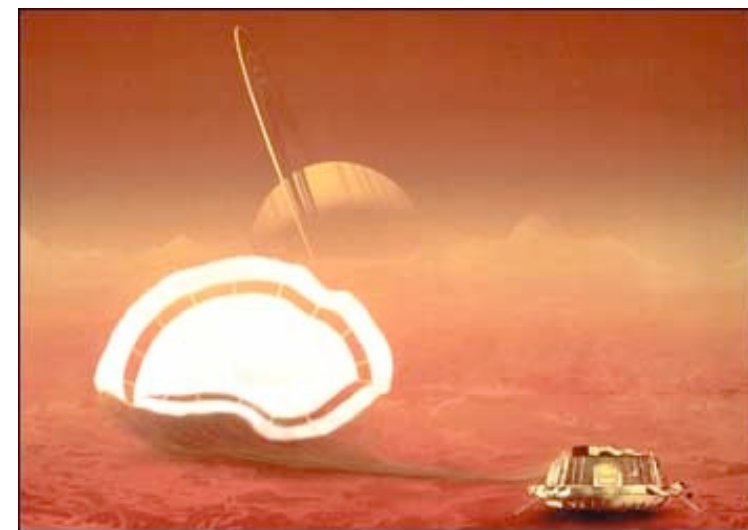
Example scenario demonstrates capture of science objectives



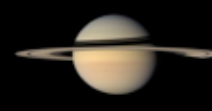
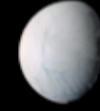
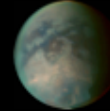
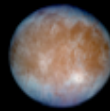
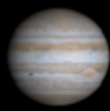


# ESA Provided *In situ* elements

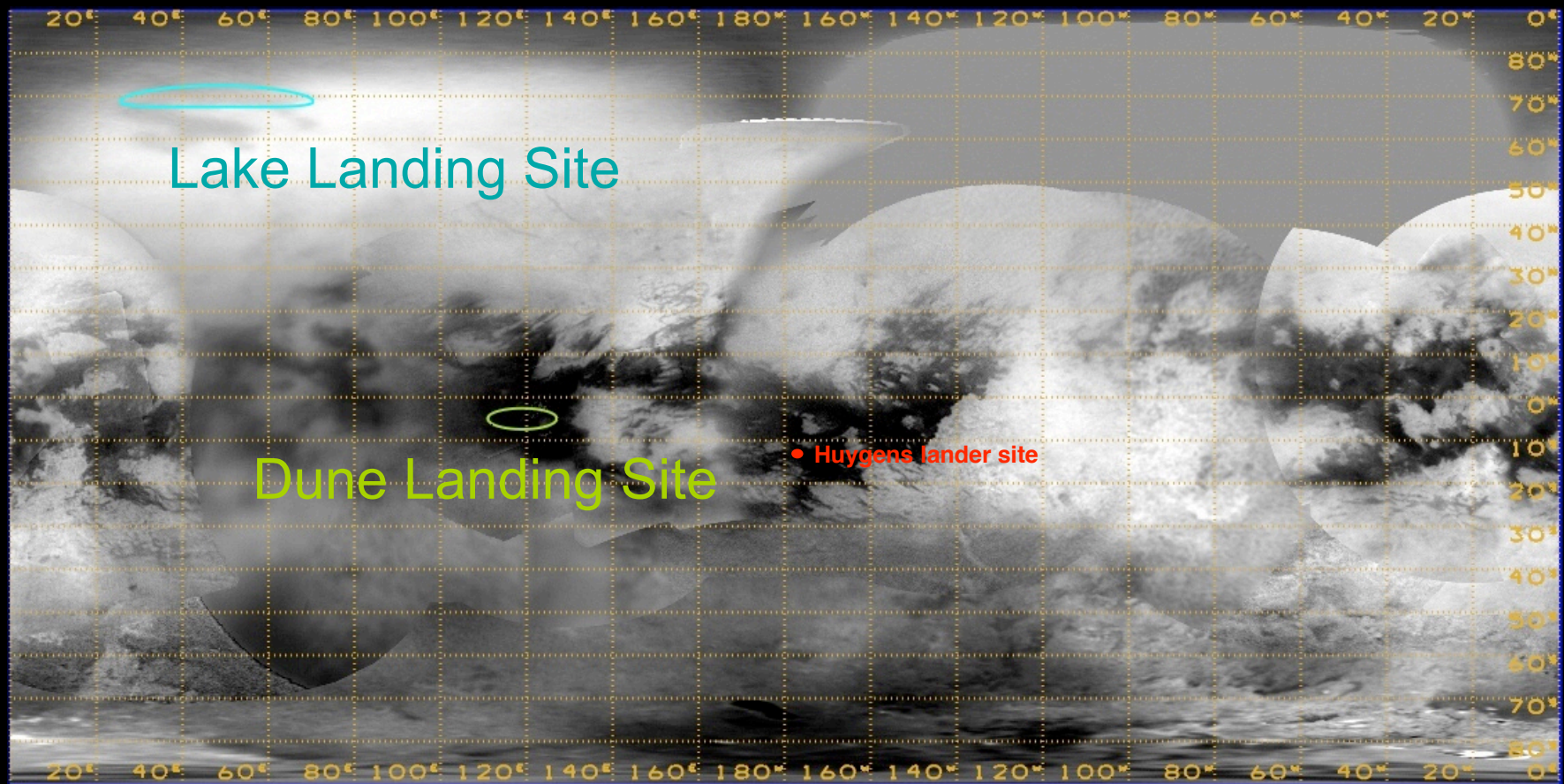
- Montgolfiere Balloon system
  - Release 6 months prior to arrival; <6km/s
  - Near equatorial to mid latitude location
  - Relay to orbiter and Direct to Earth (DTE) in Saturn tour; relay after TOI
  - Floats at 10km (+2 -8 km) altitude
  - Circumnavigates the globe
  - Lower atmosphere and surface science
  - > 1 earth year life time
- Capable Lander
  - Northern lake region and/or mid latitude
  - Very similar entry conditions to balloon
  - Similar relay options to balloon
  - Surface, hydrology and interior science
  - >1 earth month (2 Titan days) life time or >1 hr for lake landing





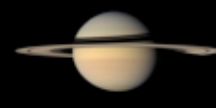
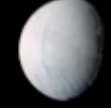
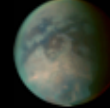
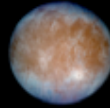


# Potential *In Situ* Entry Regions



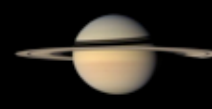
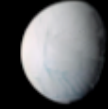
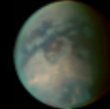
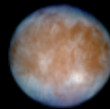
- Lander targeted to north lake region or mid-latitude
- Balloon targeted to mid latitude region

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# Summary

- Titan is a high priority for exploration, as recommended by the 2003 National Research Council of the National Academies Solar System report on New Frontiers in the Solar System: An Integrated Exploration Strategy (aka Decadal Survey).
  - Informed by recent Cassini-Huygens discoveries
- The study concept builds on a considerable basis of previous work including the Vision Missions Study, TiPEX and 2007 TE.
  - Incorporates lessons learned from Cassini-Huygens
- An orbiting mission, with current technology, could be launched in the 2016/17 timeframe or later with exciting investigations that address the decadal objectives.
  - Titan has a benign environment; even more so than Cassini-Huygens
- Accommodation of in situ elements provides additional science and instrumentation opportunities



# Notional

5/28/08

## TITAN INSTRUMENT SCHEDULE

